TRANSACTIONS

OF THE

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PHOTOMETRY AT THE NATIONAL PHYSICAL LABORATORY

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(Address delivered on Tuesday, March 10, 1936.)

ABSTRACT.—This paper gives a general description of the work of the Photometry Division of the National Physical Laboratory. The accommodation provided in the new Photometry Building is described in some detail, and an account is given of the arrangement of supplies and of the principal apparatus installed. The special lighting is also described and illustrated.

Introduction.

In an early number of the "Illuminating Engineer" there appeared a description of the rooms and equipment devoted to photometric work at the National Physical Laboratory some thirty years ago.* The rooms formed a wing of the building devoted to the electrotechnical work of the laboratory and provided a total floor space of about 5,000 square feet, including the battery room which housed, in addition to the battery exclusively employed for photometric work, two others which were wholly or partially used for the electrical work. Four members of the laboratory staff were then occupied for the whole of their time on photometry, and occasional assistance was obtained from others normally engaged on work of a different kind.

Although the variety, as well as the volume, of the work carried out in the photometry division gradually increased as time went on, for several years it was almost entirely pure photometry. Later on a number of special investigations were undertaken, particularly in connection with the Home Office Committee on Factory Lighting. This resulted in a small increase in staff, but no further accommodation was provided until after the War, when, about 1920, researches into illumination problems began to assume considerable importance. The formation in 1923 of the Illumination Research Committee of the Department of Scientific and Industrial Research gave much more permanence to this side of the work and, besides the special illumination building erected in 1922, primarily for research into problems of natural lighting, it became necessary to find further accommodation for the work of the division. This led first to the allocation of rooms having a total area of about 600 square feet in North Lodge, an old house in the laboratory grounds adopted (and to a certain extent adapted) for experimental work, and, later, to the temporary loan of about 3,000 square feet of floor space in the newly-erected building for high voltage research

Naturally, the accommodation of the work of one small section of the laboratory in four different and widely separated buildings had many disadvantages, and early in 1931 approval was obtained for the erection of a specially designed photometry building. Plans were well advanced when the financial crisis of 1931 occurred to put all such matters in abeyance for some considerable time. However, a fresh move was made in 1934, and in the autumn of that year the foundations of the new building were laid. The work was well begun by the beginning of last year and at the present time (February, 1936) nearly the whole of the photometry division is housed in its new quarters.

Fig. 1. General View of the New Photometry Building.

The New Building.

A general view of the new building is shown in Fig 1. It consists, in the main, of two storeys, but the front portion of the central section has a third floor. The plans of the various floors are shown in Fig. 2. It will be seen that the building, as it stands to-day, is not symmetrical, and reference will be made to this fact at the conclusion of this paper. The present length is 145 ft., and each floor consists of a central corridor 6 ft. wide, with rooms approximately 20 ft. deep on each side of it. The height of the ground floor rooms is 10 ft. 6 in., and of the first floor laboratory rooms 13 ft. 6 in. At the west end there is an area of about 600 square feet which is open for the full height of the building, i.e., 25 ft. The walls are of brick, but the skeleton of the building is of steel. Only the office rooms are plastered internally, and all the laboratory rooms except the life-test room are painted with a matt black paint.

The heating is provided by a hot-water system supplied from a boiler house some 140 yards away and close to the new tank building of the laboratory.

* "Photometry at the National Physical Laboratory." Clifford C. Paterson and E. H. Rayner. Illum. Eng., Vol. I., page 845, 1908.

Fig. 2. Plan of the New Photometry Building.

The lighting has, naturally, received very careful consideration. The offices are illuminated by means of totally enclosed semi-direct fittings supplemented by desk lights, while the laboratory rooms are, in most cases, lighted by direct fittings of a simple design. The long projector room, however, is lighted by elliptical enamel reflectors mounted high on the side walls, as shown in Fig. 3. This system of lighting was chosen as it was desired to keep the room as free as possible from all obstructions for the greater part of its width, so that any form of ceiling pendant was inadmissible. The workshop is provided with a number of universal-jointed wall brackets in addition to the general lighting fittings. The lighting of the dark-room presents no unusual features.

The treatment of the corridors and staircase is somewhat unusual. The upper part of each corridor is used as a duct to accommodate the many leads from the distribution boards to the various rooms and, in consequence, the height is, in each case, only 8 ft. It was therefore decided not to use pendant fittings but to instal a system of lighting from artificial windows. These are built into the back wall of the corridor and on either side of the central door, as shown in Fig. 4, the same treatment being adopted on both the ground and first floors. The arrangement of the lamps and diffusely reflecting surfaces was worked out in the Division and is shown in detail in Fig. 5. The glass used is a medium morocco, the brightness of the surface being very even and about

Fig. 3. The Projector Room.

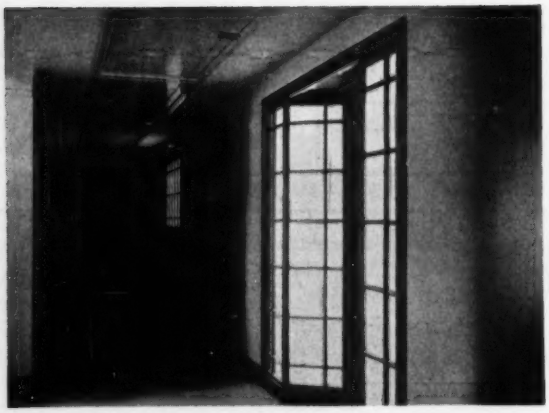

Fig. 4. The Artificial Windows in the Corridors.

five to six candles per square foot. Gas-filled lamps in bulbs having weak blue correction are used, and careful selection of these lamps was found to be necessary in order to avoid an objectionable patchiness of colour.

The lighting of the staircase is very shadowless and is provided by a series of diffusing glass columns mounted vertically in the corners at each landing, as shown in Fig. 6. The glass is tinted so as to tone with the beige decoration of the walls.

The clocks, seven in number, are driven electrically from a master housed in one of the offices, and there are seven telephone lines from the various rooms to the central exchange of the laboratory. A microphone and loud-speaker system makes it easy to call members of the staff from any part of the building.

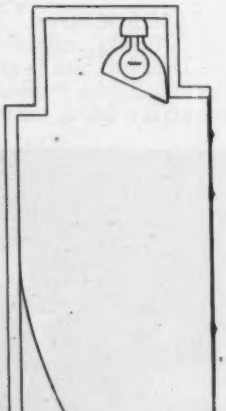

Fig. 5. Section through an Artificial Window.

Supplies.

The building is supplied with gas from the gasholder in the laboratory grounds. There is a 2-in. incoming main and a 1½-in. ring main round the building on both the ground floor and the first floor. This should provide, with ample margin, for the largest gas fittings, including high-pressure lamps, which it may be desired to measure, particularly at the open end of the large projector room, where the work on street-lighting and similar lamps will be carried out.

The electrical supplies brought into the building from the laboratory sub-station are those common throughout the laboratory, and are as follows: (i) 110 volts D.C., (ii) 240-480 volts D.C., on a three-wire system, (iii) 230 volts A.C. The last-named system supplies the lights and power plugs but like the others, it is brought to the distribution board for use for experimental purposes if desired. For, perhaps, 80 to 90 per cent. of the experimental work it is necessary to run lamps off storage batteries, and this explains the size of the battery room, viz., 54 x 25 ft. There are three 360-volt batteries rated respectively at 200, 100, and 50 ampere-hours capacity. A fourth battery for heavy current work and rated at 500 ampere-hours is at present installed in part: sixty cells are in use, but space has been allowed for this battery to be increased to 240 volts at a later date. Each of three 360-volt batteries is sub-divided as follows: 0-10-20-30-40-50-60-80-100-120-180-240-260-280-300-320-330-340-350-360, and a lead is brought from each sub-division point to a vertical copper bus-

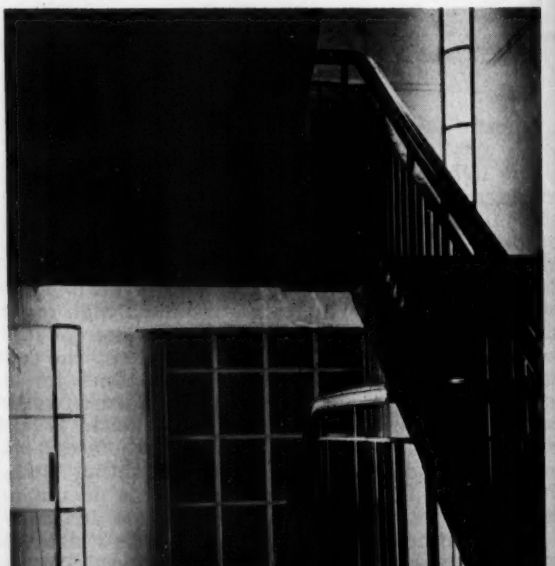

Fig. 6. The Staircase Lighting.

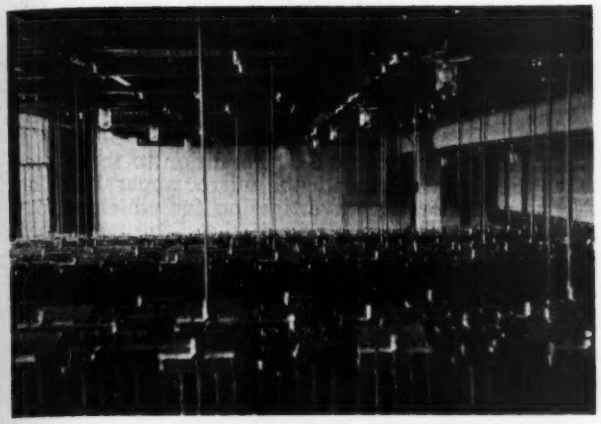

Fig. 7. The Battery Room.

bar on the distribution board. The total length of copper rod used for these leads in the battery room is over half a mile.

The design of the distribution board merits special description. It is so arranged that any section of a battery or any of the three outside supplies can be made available at the local panel in any experimental room. This is achieved by means of a rectangular co-ordinate system of bus-bars. The battery sections and supplies are connected to vertical copper strips mounted on the back of the board, while the leads to the various panels in the different rooms are connected to horizontal copper strips mounted on the front of the board. At each point where the two sets of bars would intersect if they had been laid on each other, a hole is bored through both bars and through the insulating board. A metal plug can then be inserted to connect any horizontal bar with any vertical bar, and in this way the pair of bars connected to the leads from any given room can be put across any section of any battery or across any of the outside supplies. In order to make it impossible to short-circuit a battery by connecting the same horizontal bar to two points simultaneously, the plugs are not removable from the board, but they are carried in small brass slides, one of which is movable along each horizontal bar. The slide is moved to the position corresponding to the battery section desired, and the plug is then pushed through the hole in the insulation and screwed home in a hole tapped in the vertical copper strip behind. There is, of course, a fuse in each battery lead and, for convenience, a switch between each horizontal bar and its corresponding lead. The appearance of the whole board for the rooms on the first floor is shown in Fig. 8. There is a similar board for the rooms on the ground floor.

In order to avoid mutual interference between staff working in different rooms, it is necessary to provide a large number of independent pairs of leads from local panels to the main distribution board. There are, in all, thirteen separate pairs of leads from the ground floor rooms and twenty-five pairs from rooms on the first floor. All these leads are accommodated in large ducts, which are actually the upper portions of the two corridors. Most of the leads have a current-carrying capacity of thirty amperes, but some are heavier, viz., 100 amperes. The total length of the leads from the various rooms to the distribution board is over two and a half miles. The boards in the various rooms are of the simplest possible design. Each pair of leads is connected through a double-pole knife switch and a pair of cartridge fuses to two pairs of stout brass terminals with wing-nuts.

In addition to the battery supplies and outside supplies available in any room from the distribution boards, there is the supply to the life-test racks. The regulated voltage required for life-testing electric lamps is supplied by motor-generators run off a 400-volt A.C. supply, the voltage on the output side being controlled by means of a Tirrill regulator. There are two motor-generator sets installed in the generator room. One of these is rated at 20 kVA. and the other at 5 kVA. If necessary, both can be run in parallel. The A.C. supplied by these sets is taken direct from the generator room to panels in the life-test room, and thence feeds the auto-transformers wired to the life-test frames. The controls for the motor-generators and the Tirrill regulator are placed in the life-test room.

There is provision for another generator to feed the heavy-current transformer used for running the black-body furnace employed for calibrating standards of colour temperature. This work is at present

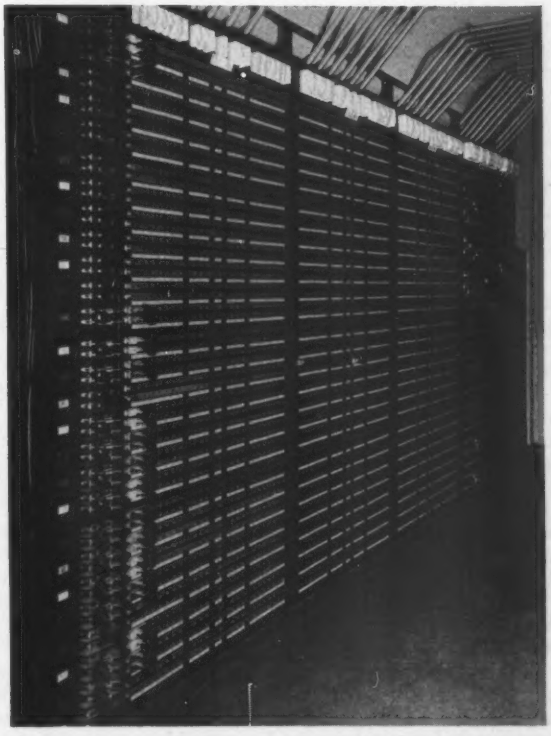

Fig. 8. One of the Battery and Supply Distribution Boards.

being carried on in the high-voltage building of the laboratory, and will not be moved for several months, pending the completion of the calibration now in progress. The furnaces will then be shifted to the furnace room in the new building, and it will be seen that this room is immediately over the generator room so as to obviate the necessity for long heavy-current leads.

It is hoped that it will soon be possible to instal in the furnace room a high-frequency induction furnace for work on the molten platinum form of the black-body standard of light. When this is done the valves required for the high-frequency generation will be placed in the furnace room.

It will be noticed that the generator room is next to the operating end of the long projector room. Thus if it should be necessary at any future time to carry out work on searchlights or other apparatus requiring exceptionally heavy currents, there should be very little difficulty in arranging supplies.

Projector Room.

As already mentioned this room occupies nearly one-half of the ground floor, running the whole length of the building, and having a breadth of 20 ft. for the greater part of its length.

At the west end, for a length of about 22 ft., the width is 26 ft. and this portion, as already mentioned, is uncovered by the first floor, so that it is open for the full height of the building, viz., 25 ft. Three important classes of photometric measurement will be undertaken here. First, there is the determination of the luminous flux output from large light sources or from fittings. For this purpose the 10-ft. sphere is used, with its accompanying photometer bench. Then there is the determination of the light distribution curves of lamps and fittings, using the mirror apparatus in which the source is carried at the end of an arm movable about a central horizontal axis about 5 ft. 6 in. above ground. A 45° mirror, also rotatable about this axis, reflects the light from the fittings to a photometer head movable along a 3-metre bench. This bench is itself movable along a track defined by a metal rail let into the floor for the whole length of the projector room. The mirror apparatus is so placed with respect to this rail that the axis of the bench, as it moves up and down the room, coincides with the axis of rotation of the mirror.

The third piece of apparatus is not yet constructed, but is also to be used for the determination of light-distribution curves and iso-candle diagrams, especially in the case of heavy or bulky fittings. The fittings will be suspended from the top of a small turret provided at the back of the west end of the building. This makes it possible to have the luminous centre of the fitting very nearly at the level of the main ceiling. It will, therefore, be possible to move a photoelectric cell, or other photometric device, in a quadrant centred on the fitting and having a radius of nearly 25 ft.

Finally, the projector room is used for the measurement of all kinds of projection apparatus, such as automobile headlights, rear reflectors for bicycles, signalling apparatus and, possibly, searchlights. For the last named it is necessary to contemplate measurements at long distances, and, therefore, the greater part of the east wall of the projector room is occupied by a steel roller shutter which can be opened to give a clear range of about 650 ft. without obstruction.

The projector room cannot, of course, be entirely devoted to the work just described. There is another photometer bench, in addition to those used with the sphere and with the mirror apparatus. This is available for any investigation for which it may be required, e.g., the study of the diffusing properties of materials, the measurement of ships' navigation lights, etc.

Physical Photometry Room.

The only experimental room on the ground floor, other than the projector room, is devoted to physical photometry, and the whole of this side of the work of the division, other than the routine photometry of electric lamps, is carried out here. This room is 16 ft. by 25 ft. and houses (i) a three-metre bench and a one-metre sphere for the photoelectric measurement of candlepower, (ii) a one-metre sphere and auxiliary apparatus for the measurement of luminous flux, (iii) a photoelectric spectrophotometer, and other apparatus for studying the characteristics of photoelectric cells and their associated colour correction filters and (iv) various apparatus required in testing cells for conformity with the British Standard Specification. The testing of photoelectric illumination photometers is also carried out in this room.

Spectrophotometry and Illumination Research.

The portion of the first floor behind the corridor is divided into two unequal portions by means of a single brick partition about 84 ft. from the east wall. The smaller of the two rooms thus formed is the life-test room, while the other has been subdivided by a number of temporary partition walls into five smaller rooms. The partitions are constructed of a light wooden framework covered with fibre board, and are painted a matt black like the other walls. The object of this arrangement is to provide for changes in the programme of experimental work. One room, 13 ft. 4 in. by 20 ft., is at present used for visual spectrophotometry, while the other four rooms, shaped as shown in Fig. 2 are used for the illumination research work, particularly that associated with the study of glare and of visual characteristics generally. Much of the apparatus used for this work is a more or less temporary assemblage of different instruments and specially constructed elements. The length of time for which it is required depends on the nature of the problem, and may be anything from a few months to several years. It may well happen that the size and shape of room which is most convenient to-day will no longer be suitable two or three years hence. If this should prove to be the case, the present temporary partitions can readily be moved to suit the new requirements.

Life-Test Room.

The remainder of the first floor behind the corridor is the life-test room, in which are the steel skeleton frames which carry the lamps undergoing a life-test

or a period of burning preliminary to standardisation. The three frames, which have been in use from the early days of the laboratory, and which were described in the paper mentioned earlier, have been re-wired and re-erected in the new life-test room, and a fourth frame of similar construction has been added to accommodate the larger number of lamps now commonly on life-test at one time. The opportunity has been taken, too, to provide space for the life-testing of gaseous discharge lamps. The control panel for the motor-generators and Tirrill

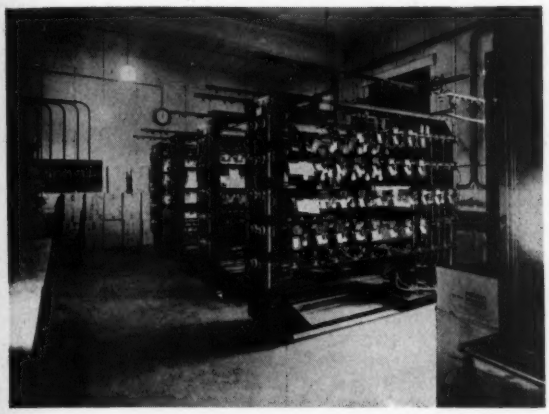

Fig. 9. The Life-Test Room.

regulator used for supplying the life-test frames is placed in the life-test room, the machines themselves being, of course, in the generator room on the ground flood. There is ample gas supply available in this room, so that life-tests on gas lamps can also be carried out if required.

Furnace Room.

The large room situated at the west end of the building, immediately over the generator room, will be used for the work on the colour temperature scale. Hoisting tackle, movable along a special girder in the roof, will facilitate the movement of the heavy furnaces and other equipment used in this work.

At a later stage, it is hoped to instal in this room a high frequency induction furnace for use in establishing the primary standard of light and maintaining the sub-standards derived from it. The proximity of this room to the generator room will be a great convenience.

The Photometry Rooms.

The room next to the furnace room is L-shaped and adjoins another room of identical size and shape. These two are the rooms devoted respectively to the routine photometry of light sources and to the measurement of sub-standards and other high precision work. The equipment in the former room, known as the "commercial photometry" room, consists of two one-metre spheres with their appropriate photoelectric and other auxiliary apparatus. One sphere is also equipped with a photometer bench so that it can be used for visual as well as photoelectric photometry. There is space in this room for at least one more sphere should an increase in the amount of routine photometry make such an addition necessary at a later date. This room is opposite the life-test room so that lamps can easily be carried backwards and forwards from one to the other.

The equipment in the "standards room" consists of a 4-metre photometer bench, with potentiometer and electrostatic voltmeter. The newly constructed apparatus for rotating vacuum lamps, and so deriving sub-standards of luminous flux from sub-standards of luminous intensity is kept and used in this room. The partition wall between the two photometer rooms has an opening, 3 ft. square, so placed that an uninterrupted run of over 40 ft. may be obtained if desired.

In the past it was usual for most of the work connected with the preparation of sub-standards of luminous intensity to be done in the standards room. With the better accommodation now available in the commercial photometry room this is no longer necessary and the standards room can therefore be reserved for the preparation and inter-comparison of the sub-standards kept and used in the Division and for research work involving bench photometry of the highest precision.

Workshop, Dark-room, etc.

On the first floor at the east end of the building there is a room 15 by 25 ft., described as the workshop. This is, to a certain extent, a misnomer for the staff of the Photometry Division of the Laboratory does not include any mechanics. The construction of experimental apparatus, if of metal, is done chiefly in the large workshops of the Metrology and Engineering Departments or, if of wood, in the workshop of the Electricty Department. Nevertheless, it is necessary to have workshop facilities on a minor scale for the use of the Scientific and Assistant staff of the Division. At present there are no machines but it is hoped later to instal a small lathe and, possibly, a drilling machine. There is a fume cupboard which is a great convenience for such purposes as the making of selenium cells, the magnesium-smoking of diffuser surfaces and similar fume-producing processes.

On the second floor there is a small photographic dark-room with simple equipment, including an enlarger.

In one of the offices on the ground floor there is a strong room in which are kept certain of the sub-standards of the Division, the international blue glass used for stepping up from the primary standard to higher colour temperatures, and any particularly valuable apparatus, such as the platinum ingots used for the primary standard of light.

A small library of books and periodicals dealing with photometry and illuminating engineering, books of tables, and certain reference books is housed in another office, but this is very restricted in scope and is only supplementary to the main library of the Laboratory.

Other Accommodation.

It has already been mentioned that the work on the colour-temperature scale, now being carried on

in the high-voltage building, will not be moved for some months to come. Apart altogether from this, there is certain work which will continue to be carried on outside the new building almost indefinitely. The roof of the high-voltage building, over 60 ft. above ground level, provides an ideal site for the daylight illumination recorder, and there is at present no intention of moving that. Further, the illumination building will continue to be used for much of the illumination research, especially in the domain of natural lighting. The experimental street-lighting system along Kelvin-avenue, the communication road to the north of the illumination building, will also remain available for use when needed.

In the early part of this paper mention was made of the fact that the new building as it stands to-day is not symmetrical; it is, in fact, 60 ft. shorter to the east than to the west. This arrangement is deliberate, and the argument for it is based on the really remarkable increase which has taken place in the work of the Division during the past ten or fifteen years. Illuminating engineering is still a very young subject and one in which no small amount of further research and experimental work still remains to be done. Further, the demands for lighting of all kinds are growing rapidly, and there is a corresponding increase in the facilities for illumination and in the number of types of light sources generally available. This indicates that, quite apart from research, the regular photometric work of the laboratory is likely to increase in volume for some time to come. It was, therefore, thought wise to plan the new building so that extra accommodation could be provided in the future without any interference with the general plan and lay-out of the building and its services. In particular the battery room and the distribution boards are designed to accommodate extensions and a number of additional circuits without any alteration to the existing plant.

Forthcoming Events.

Oct. 13th. Opening Meeting of the ILLUMINATING ENGINEERING SOCIETY; Presidential Address, Report of Progress and Exhibits *(E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, Strand, London, W.C.2)*. **4.30 p.m.,** preliminary **Inspection of Exhibits; 5.30 p.m., Meeting** and **Demonstrations.**

Similar Meetings have been provisionally fixed for local circles in Manchester (Oct. 20th) and Glasgow (Nov. 3rd).

Oct. 27th. Discussion on **"Statutory Regulations on Lighting a Help or a Hindrance?"** *(Informal Meeting of the Illuminating Engineering Society at St. Ermin's Hotel, Westminster, S.W.1)*; **6.30 p.m.**

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

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